Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

**Faculty of Veterinary Medicine and Animal Sciences**

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## Kotrafik i ett automatiskt mjölkningskarusellssystem

### – Jämförelse mellan enkelgång och öppen väntfålla

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Degree project 30 credits

Uppsala 2017

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**Credits:** 30 credits
**Level:** A2E
**Course title:** Degree project in Animal Science
**Course code:** EX0551
**Programme:** Agriculture programme – Animal Science

**Place of publication:** Uppsala
**Year of publication:** 2017
**Title of series / Number of part of series:** 613
**Online publication:** http://stud.epsilon.slu.se

**Keywords:** Cow traffic, automatic milking rotary, automatic milking, milking time, dairy cows, waiting area, cow behavior

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# Abstract

In automatic milking systems it is of great importance that cows voluntarily enter the milking unit, negative experience of milking can influence motivation for entering the unit and in turn affect both production and health. Batch milking in an automatic milking rotary (AMR$^{TM}$, DeLaval International AB, Tumba, Sweden) enables several cows to be milked at the same time. A holding area before the entrance to the rotary often supplements this system. Studies have shown if more time than 2.5 hours a day is put into the total milking procedure milk production may decrease, since the long time away from pens will affect the time put on feed intake and the time spent resting. The layout of the holding area might influence the cow traffic and the milking efficiency and for this reason, a single alley (SA) and a more traditional open waiting area (WA) were compared to estimate the effects on milking time and social interactions as well as labor time for herding cows into the AMR. A total of 138 lactating cows of Swedish Red and Swedish Holstein breeds were included in the study, and divided into two groups; the *G1* group consisted of mostly primiparous cows and the *G2* group of mostly multiparous cows. After cows were collected for milking, staff was not permitted to interact with cows for 40 minutes, unless downtime occurred in the AMR. Labor for herding cows after these 40 minutes was calculated. The treatments were applied for 14 days, and data was collected for the last 6 milkings of each treatment period that were successfully completed. Behavior data was analyzed for treatment differences using Student's t-test in Excel and automatically collected data on milking times was analyzed using Proc Mixed in SAS. The results showed a higher frequency of interactions in SA compared to WA ($p < 0.01$). For the treatment WA, *G1* performed overall more interactions compared to *G2* ($p < 0.05$). No difference between treatments was found for time required for the overall milking time, although differences were found between groups. A higher proportion of cows in *G1* entered the AMR voluntarily, and waiting time was shorter for *G1* ($p < 0.01$). When staff interacted with cows, less time was spent on herding the *G2* group ($p < 0.05$). In contrary, less time in total was spent on the milking for the *G1* group ($p < 0.05$). Generally, total time away from pens was long (> 75 minutes), which probably would affect cows production and health. The two treatments differed with regards to social interactions, but it cannot be determined if interactions in the restricted area correspond to the whole holding area. Therefore, more research should be conducted to evaluate if any of these two systems affect the prevalence of interactions.

# Introduction

Automatic milking (AM) has been developed during the last three decades and has been in commercial use in Europe since 1992. In the beginning of the 21$^{st}$ century, more than 90 % of all AM system operated farms were located in the northwestern parts of Europe (de Koning & van de Vorst, 2002), 9 % in Canada and only 1 % in USA (Jacobs & Siegford, 2012). The market for AM has been strongest in countries with high milk production and where labor is expensive (Svennersten-Sjaunja & Pettersson, 2008; de Koning & van de Vorst, 2002). During the year of 2009, a total of 500 herds with AM were operating in Sweden (Gustafsson, 2009) and about 8000 in total around the world (Jacobs & Siegford, 2012). More recent figures show that about 90 000 of all Swedish dairy cows where housed in an AM system during 2016 (LRF Mjölk, 2017) which corresponded to 27 % of all dairy cows in Sweden (Swedish Board of Agriculture, 2017). One of the newest systems on the market is the automatic milking rotary (AMR™, DeLaval International AB, Tumba, Sweden) that was launched in 2010. The AMR has 24 milking places with 5 robotic arms. An AMR of this size is designed to operate herds of 300 to 800 dairy cows with a milking frequency of two milkings per day and an ability of milking 90 cows per hour (Jacobs & Siegford, 2012).

AMR with batch milking is a production system that can be seen as a semi-construction of conventional rotary milking and AM systems with a single box unit. Cows are gathered into a confined area prior to milking by the staff, and should thereafter proceed to milking without any further guidance. Different designs of the area before milking can affect both the flow of cows into the AMR and the interactions between cows in the confined area (Wierenga, 1990; Dahlgren, 2013). It has been shown that a long waiting time before milking can have a negative effect on milk production and health (Grant, 2007). It is therefore of interest to examine dairy cow behavior, the time spent milking, and the use of labor in AMR with two different holding area designs: single alley (SA) and open waiting area (WA).

# Aim and hypotheses

The aim of this study was to compare a SA with a WA between the housing area and the AMR, with focus on cow behavior and productivity.

The hypotheses were that 1) WA would give cows better conditions for social interactions than in a SA, 2) the WA would have a higher efficiency since more cows have access to the entrance into the AMR and that 3) the SA requires less labor for pushing cows to enter the rotary.

# Literature study

## Housing and management

The design of a stable sets the outer limits of how well the production will function for both cows and staff. How cows move around in the stable is referred to as cow traffic and largely depends on the layout of areas where cows are housed. In fully automatic milking (AM) systems it is particularly important to construct stables that allow good cow traffic as the system relies on activity among the cows both day and night (Jacobs et al., 2012). Fetching cows for milking is both time consuming and is influencing the cows' own initiative for voluntarily going to the milking and should be limited to a minimum (Van Dooren et al., 2004). AM has the advantage of having a consistent milking routine which cows get used to. AM is not suited for all cows due to poor udder conformation or personality, as anxious cows are more likely to interrupt milking by kicking or stepping (Svennersten-Sjaunja & Pettersson, 2008; de Koning & van de Vorst, 2002) and will therefore increase the workload due to fetching of cows and manual help to be milked successfully (Gustafsson, 2005).

Arguments for using AM systems are the reduced need of labor for the daily milking routines (Jacobs & Siegford, 2012) and less heavy work (Stal et al., 2003). One of the largest costs in dairy production is the cost of labor (Gustafsson, 2009), in Sweden it has been found to constitute around 24 % of the total cost per kg ECM (Hedlund, 2008). A rotary parlor showed the lowest work time for labor associated with milking of all batch milking system with a time of 2.15 minutes per milked cow and day (MPMC). The AM system with a single unit only required labor of 0.89 MPMC (Gustafsson, 2009). Another advantage in AM systems was a decrease in required time for each cow in larger herds (Gustafsson, 2009). Smaller herds could also benefit, where having 55 lactating cows would result in 2.5 hours of labor saved daily using an AM system (Gustafsson, 2005). Although work time of milking decreased, this time is still needed for working in the stable and monitoring cows (Gustafsson, 2005).

Cows are usually housed in loose housing systems with a lying area, feed and water available, and grouped according to body condition, age, udder health etc. At milking, cows usually are collected, all at the same time, and brought to a holding area (HA). A closed HA before milking ensures that all cows will go through the milking unit (MU) before entering the pens again (Uetake et al., 1997). The management in a dairy herd with an automatic milking rotary (AMR) and batch milking can be compared with conventional milk production, except that the milking procedure is performed automatically.

Albright et al. (1992) stated that the key to a fast and efficient entrance into the parlor is a well-planned HA. The HA should be dimensioned according to the throughput of the milking system (Albright & Arave, 1997). Recommendation on the size of a HA is available from the International Commission of Agricultural and Biosystems Engineering and states 1.4 – 2.0 $m^2$ per cow (Flaba et al., 2014). The dimension of the HA also relies on other factors, such as horn prevalence and body size. The comparable recommendation in Swedish regulation for cattle in confined areas is during transportation where 1.6 $m^2$ and 2.2 $m^2$ is stated for 550 kg respectively 700 kg body weight, at road carried vehicles (Swedish Board of Agriculture, 2010). Irrgang et al. (2015) found that a space allowance of 2.5 $m^2$ instead of 1.7 $m^2$ for each cow resulted in both less injuries and aggressive behavior when cows were horned. Studies have also showed that larger space allowance in the HA for each cow would increase the frequency of rumination, which is associated with wellbeing in cattle (Dijkstra et al., 2012).

Earlier investigation on shape and size of the HA has been done and three different layouts in an AMR system were evaluated. Results showed that a SA would decrease the frequency of aggressive interactions. Time spent on herding cows also decreased in the SA (Dahlgren, 2013). Designs of walls and floors also may affect the cow traffic. Solid walls will make cattle walk more easily through a SA, as they will be focused on the exit of the alley rather than the surrounding. It has also been suggested that a curved alley is favorable since it prevents cows to see what is in front of them (Grandin, 1980) and for ease of herding by using cows flight zone (Grandin, 1997). In parlor milking it has been suggested that a wide straight entry is favorable, and that it should be located as close to pens as possible to decrease walking distance and to get a more efficient entry (Albright & Arave, 1997). Additionally, it has been demonstrated that cows are more active when walking on soft flooring compared to harder ones (Jungbluth, 2003). Cook and Nordlund (2009) stated that rubber flooring in HAs and long raceways reduce claw lesions, compared to concrete flooring. A slope of the HA will ensure that cows stand in the right direction to the entrance since cows prefer to stand uphill (Albright & Arave, 1997).

### Social behavior and hierarchy

The behaviors of cattle can be split into five behavior classes: maintenance, social, reproductive, feeding, and maternal-calf behavior (Albright & Arave, 1997). Social behaviors can be further subdivided into agonistic and non-agonistic behaviors, which includes aggressive interactions respectively non-aggressive interactions (Bouissou et al., 2001). These consist of communicative behaviors such as body movements, vocalization, and physical interactions to mention a few examples (Albright & Arave, 1997). It is with different aggressive social behaviors the hierarchy in a group of cattle is established (Albright & Arave, 1997; Rousing & Wemelsfelder, 2006). Aggressive behaviors include actions of fighting and threatening (Beliharz & Zeeb, 1982) and are described by DeVries and von Keyserlingk (2006) as interactions where a butt or a push is performed against another cow. The difference between actions of high rank and aggression is the outcome of the behavior. An act from a high-ranked cow will lead to an inhibition of a behavior from the receiving animal where as an aggressive interaction will cause the other animal to strike back (Beilharz & Zeeb, 1982; Albright & Arave, 1997). The establishment of the hierarchy between two cows can be set in different ways. If one cow is bigger, stronger, older or healthier a simple threat may set rank order between these two animals. When two individuals are more similar in age, size and health status, a physical contact of a head-to-head pushing or butting will determine the highest rank winner (Albright & Arave, 1997). A high-ranked cow is not necessarily aggressive, but has probably been aggressive to reach the current status. A steady relationship between two individuals eliminates the need for more aggressiveness (Beilharz &

Zeeb, 1982) and makes it possible for involved cows to predict the outcome of an interaction between each other (Wierenga, 1990).

In 41 % of all pairs of cows with dominance hierarchy both members will displace the other one, independent of dominance status; although subordinate cows only initiate 10 % of the aggressive interactions. This shows that the aggressive interactions within a pair are not random (Wierenga, 1990). Contradictory displacements are an action of the housing system since cows are competing for recourses. This makes the interactions artificial (Wierenga, 1990). Competition for recourses has been shown to be the factor for most displacements (Wierenga, 1990). If the entrance of the MU is considered a resource, this activity may increase the displacements, if found as resource worth fighting for. Evaluation of this can be conducted by video analysis, and is to prefer since several interactions can occur at the same time. These interactions are of short duration with several bouts that makes continuous registration of behaviors necessarily (Chen et al., 2016).

By increasing the feeding space from 0.5 m to 1.0 m per cow, the aggressive interactions could decrease due to less competition of feed (DeVries et al., 2004). An interaction directed against the head of a cow is perceived as threat more than towards another body part. Fighting among cattle is often an action of head-to-head and followed by head-to-neck interaction (Bouissou et al., 2001). When aggressive interactions occurs from behind the response from the attacked animal vary, independent of the hierarchy status of the actor or attacked animal, the response is instead based on how the situation is perceived by the attacked animal (Wierenga, 1990). Variations in the number of displacements have a large spread between cows, indicating how diverse the cows' behavior in a group is (Wierenga, 1990). Some animals also tend to direct their antagonistic interactions towards some specific individuals in the group (Wierenga, 1990).

Dairy cow welfare is affected by several factors such as social interactions between cows, interactions between human and cow, management system, barn design and feeding (Jacobs & Siegford, 2012). The sympathetic nervous system is activated when the animal experience fear or discomfort, which would be the response of an aggressive interaction (Rushen et al., 2008). Cows put in a confined area have limited possibility to avoid aggression, which might affect their wellbeing. Activation of the sympathetic nervous system can impede milk ejection in several ways; reducing oxytocin secretion from the pituitary gland, inhibit the response of the myoepithelial cells to oxytocin, reducing blood flow to the udder, and contract the sphincter at the tip of the teat (Tancin & Bruckmaier, 2001). Only cisternal milk can be removed without a milk ejection. This fraction is less than 20 % of stored milk in the udder, remaining is stored in the alveoli. Without milk ejection milk production will decrease due to the inhibitory effect milk has on the secretory tissue, and the risk for infection in the udder will increase (Bruckmaier, 2005). A decrease in milk production can be used as an indicator of reduced welfare. Stressors such as novel surroundings and fear of human contact at milking can inhibit milk ejection (Rushen et al., 2008) due to central inhibition of oxytocin release (Wellnitz & Bruckmaier, 2001).

During natural conditions for cattle, it is rare that new females are added to an existing group of females (Bouissou et al., 2001), but in dairy production this is a common procedure. Regrouping is performed in order to form homogenous groups of cows with e.g. similar production level, udder health, gestation status and body condition. Although this routine will increase aggressive interactions, the reason for regrouping is to maintain a good health and welfare status (Bøe & Færevik, 2003). It has been shown that regrouping results in a ten-folded increase of antagonistic behaviors in the hours after the new constellation of the group (Bouissou et al., 2001). Primiparous lactating cows changed their behavior when being regrouped; aggressive interactions increased, milk production decreased, more time was devoted to standing and each lying session were shorter during the 3 weeks the experiment was conducted (Hasegawa et al., 1997). Heifers that are habituated to groups with milking cows and introduced to the milking system 3-weeks before calving have higher milk production, lower somatic cell count (SCC) but seemed to have lower fertility (Wicks et al., 2004).

### Milking and waiting time

In batch milking, all cows are gathered and taken to the milking at the same time. Moving together with herdmates in a group has been suggested to correspond to the natural behavior of cattle since the movement of one cow results in movement of the next one (Doyle & Moran, 2015). In large dairy herds, the individual groups of cows may also be large which could lead to long waiting time for milking and might affect production, welfare and health. Top 10 % producing cows within a herd showed longer resting time and less time standing in alleys and perching in stalls compared to the herd average (Grant, 2007). Dairy cows approximately need 21.5 hours a day for accomplishing their needs of resting, eating, grooming, social interactions and rumination. Only 2.5 h are remaining each day for transportation to milking, waiting in prior to be milked, milking and getting back to the pens (Grant, 2007). Research of milking in AM system with single box stall has shown that time spent waiting in the HA on average were 1.5 h a day, but had a variation of 0.5 h to 3.5 h daily (Munksgaard et al., 2011). If cows are away from pens for longer than 2.5 h daily time spent on other activities will decrease as the milk production. Feeding and resting time will be reduced first, which in turn can impair milk yield and health (Grant, 2007). Lameness is positively correlated with time spent away from pens (Espejo & Endres, 2007; Gomez & Cook, 2010). In a study by Espejo and Endres (2007), time spent away from pens varied between 2.8 to 5.85 hours daily. It is also suggested that the hierarchy in the group affect the prevalence of lameness where low-ranked cows has higher frequency (Galindo & Broom, 2000).

Low-ranked cows spent more time waiting in the milking queue compared to high-ranked cows in an AM system with forced cow traffic (Forsberg, 2008). In a simulated hierarchy study, with an AM system, low-ranked cows spent 68.9 min in relation to high-ranked who only spent 3.5 min (Halachim, 2009). Melin et al. (2006) showed that average waiting time for low-ranked cows was 20 min and for high-ranked cows 13 min, in an AM system with forced cow traffic in a single MU where 46 cows was milked. In the same way Ketelaar-de Lauwere et al. (1996) states that lower dominance in cows will make them spend more time waiting prior to milking. They also concluded that low-ranked cows would spend more time lying in the cubicles (Ketelaar-de Lauwere et al., 1996).

### Motivation and milking order

In an AM system it is of great importance that cows voluntarily visit the MU (Jacobs & Siegford, 2012). Albright et al. (1992) investigated the willingness of cows to voluntarily enter a milking parlor by observing cows during 85 milking and providing 12 222 observations. Findings showed that only 2.8 % of cows in the study entered voluntarily without any assistance. According to de Koning and van de Vorst (2002) the main motivation for a cow to visit an AM is the supply of concentrate since it is an attraction for entering the MU. Prescott et al. (1998) also found that the motivation for being milked is low, but cows have a high motivation for feed. By supplying feed in the AM cows attend more frequently (Prescott et al., 1998). Feed availability in the MU may therefore affect the cow traffic. In a study by Kolbach et al. (2013) was it concluded that the absence of feed would negatively affect the cow traffic in an AMR system where voluntarily entrance into the MU was adapted. Although, Prikelmann (1992) concluded that both availability to concentrate and roughage were suitable for motivating cows to visit the MU. Either by supplying concentrates in the MU or by locating the MU between lying area and feeding area in a forced cow traffic system.

Albright et al. (1992) found that the highest yielding cows would enter the two first milking places in a double 5 herringbone parlor and the lowest yielding cows in the last places. High milk yield has a significant correlation with being first in the milking order (Rathore, 1982). Rathore (1982) also showed that cows entering the parlor earlier had lower SCC compared to cows that entered later, indicating that cows that enter earlier both had higher production and a lower SCC. It has been suggested that cows with high milk production may find the milking as a relief of pressure in the udder, motivating them to enter earlier (Rathore, 1982). Neither Albright et al. (1992) or Rathore (1982) explained in their design the performance of cows, e.g. lactation stage, milk yield, age. This makes these results hard to evaluate.

In a study of a rotary system by Soffié et al. (1976) was it found that the cow that exits the housing area first is also the first to enter the parlor, but the rest of the order in the herd did not show a consistency. Cows were let out from the housing area through a wider exit gate where several cows could pass by. The cows that entered first had a high social position in the group, but were not dominant. The hierarchy within the group was calculated and the correlation between milking order and dominance value were low or not significant. It was also found that correlation between milking order and milk production did not exist (Soffié et al., 1976). Winter and Hillerton (1995) observed a constant milking order in an AM system with forced cow traffic where concentrate was available in the MU. However, the order was probably a consequence of the feeding behavior within the group rather than milking order since concentrates were supplied in the MU and roughage available after passing through the MU. Olfosson (2000) showed that high-ranked cows would often get access to the MU before cows with lower rank, and they also had a higher milking frequency compared to low-ranked cows.

# Material and methods

## Animals, Management, and Housing

This study was conducted at Lövsta research center, Swedish University of Agricultural Sciences, Uppsala. In total, 138 dairy cows of the Swedish Red (SRB) and Swedish Holstein (SH) breed from two different groups (*G1* and *G2*), were enrolled in the study, although not every cow was present at all times. During the experiment cows and heifers were introduced to the groups continuously and cows were also removed continuously due to health issues and drying off. *G1* consisted predominantly of primiparous cows and *G2* predominantly of mulitparous cows. Heifers were introduced to the AMR before calvning and housed in *G1*.

Cows were milked twice daily at approximately 05:30 and 15:30, in the DeLaval Automatic Milking Rotary™ (AMR™), with quarter level milking and 24 milking places (MP). In the AMR, four robotic arms prepared the udder; two arms cleaned and pre-milked the front and rear teats, and two arms attached the teat cups. After milking, another robotic arm applied teat spray. The robotic arms that clean and pre-milk had an operating time of 35s, arms that attach teat cups had a maximum working time of 50s and maximum time for the arm operating teat spray was 30s. The time-out set for the AMR was 60s, which means that if the AMR had been inactive for 60s, i.e. no cow had entered the available MP, the AMR rotated one MP. Milking order for the two groups was fixed, starting with *G1* and continuing with *G2*.

The cows were housed in a free-stall system with 64 cubicles in each pen. The stocking density was ≤ 1:1 (cow:cubicle). Each pen had four rows of cubicles, separated by concrete alleys with automatic manure scraper. All alleys had concrete flooring with grooves, except for one alley in front of the feeding places in *G1* where a rubber mat was laying on top of the concrete. The feeding area differed between the groups in number of feeding places, *G1* had 22 places; cow:feeding place ratio of 3:1, and *G2* had 33 places; cow:feeding place ration of 2:1. Both pens had four concentrate feeders each. Cows were fed silage *ad lib.* and concentrates according to their calculated requirements (Volden, 2011) according to their individual milk yield. In the raceway to the milking area, the slatted concrete floor was partially covered with rubber mats. In the curved SA and the WA the flooring consisted of grooved concrete, flooring in the AMR consisted of rubber mats. No crowding gate was used in the HA.

## Study design

In this study two cow traffic systems, SA entrance and WA (fig 1), in front of the AMR were examined. Each treatment period lasted 28 milkings (14d) with data collection during 6 milkings, both morning and evening milkings, the last week of each treatment period (table 1). To obtain data comparable between the two treatments, the area of the SA and the WA were approximately at the same size, 100 $m^2$, which corresponds to the recommended area of 1.4-2.0 $m^2$ per cow (Flaba et al., 2014). In order to evaluate these two systems, social interactions and efficiency with regard to milking time and herding time were taken in consideration.

*Table 1*. Treatments, duration of each period, and which milking days that were analyzed. Analyzed milkings were collected from the measure period. Aiming for analyzing milkings that were longest into the measure period.

| **Treatment** | **For-period** | **Measure period** | **Analyzed milkings** |
|---|---|---|---|
| SA | 14 milkings (7d) | 14 milkings (7d) | 6, 9, 11, 12, 13, and 14 |
| WA | 14 milkings (7d) | 14 milkings (7d) | 5, 6, 8, 9, 13, and 14 |

## Milking routines

Before milking, cows were gathered from the pens into either the SA or the WA by staff. A gate was closed behind them, and from this time stamp, staff were not allowed to interact with the cows for 40 minutes, unless the AMR had been inactive for 10 minutes. If the AMR had been inactive, staff were permitted to herd the cow blocking the entrance into the milking unit. After 40 minutes had elapsed, the staff were permitted to complete the milking according to the normal milking routines.

Cows that were not completely milked during the 40 minutes, were redirected to enter the AMR again, although it has been demonstrated that one incomplete milking of an udder quarter did not show any negative effects of milk yield or SCC for cows in mid and late lactations compared to redirected cows (Nilsson, 2016; Lidholm, 2016). If the same cow still did not get milked completely, she was directed to a small waiting area (SWA; fig. 1), brought to the AMR by the staff and was milked with the remaining of the group. This routine took place in accordance with the staff in the research herd. Cows not suitable in the AMR, i.e. the robotic arms never succeed to attach the teat cups, were set on no milking and were always redirected to the SWA to be manually milked last within the group.

Exceptions from mentioned routines were made for cows that were new in the system. Staff made sure of a complete udder emptying for these cows during the first four consecutive milkings. Exception was also made when CMT (California Mastitis Test) and bacteria test were needed, and then collected together during one milking a week.

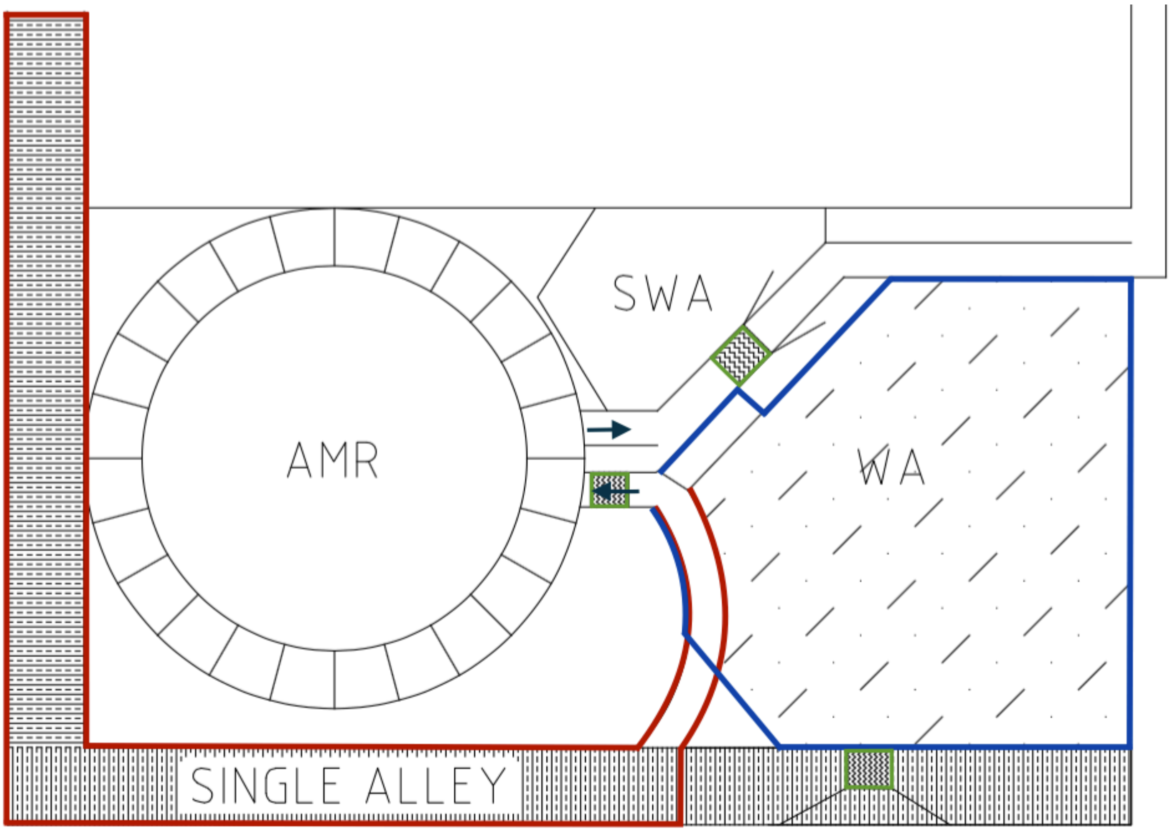


*Figure 1.* Outline of two cow traffic sysems included in the study. Red lines show where cows were located during the exeprimental design SA. Blue lines show location of the WA. Three selection gates are plotted, marked by green lines; one is located in the raceway to the WA, one at the entrance to the AMR, and one after milking where cows are either redirected back to the AMR, back to the feeding area in respective pens or to the SWA to the left. Arrows show enterence and exit in the AMR.

## Data collection

### Behavior registrations

Behaviors were registered by five surveillance cameras. These were located around the AMR and in the raceway to the milking (fig. 2). Four cameras were placed around the AMR (Fisheye view, SAMSUNG SNF-8010VMP), and the fifth camera was placed either in the beginning of raceway to the AMR or in the WA (regular view, SAMSUNG QNV-7010RP) (fig. 2). A 32-channel network video recorder was used for the recording (SAMSUNG XRN-2011).

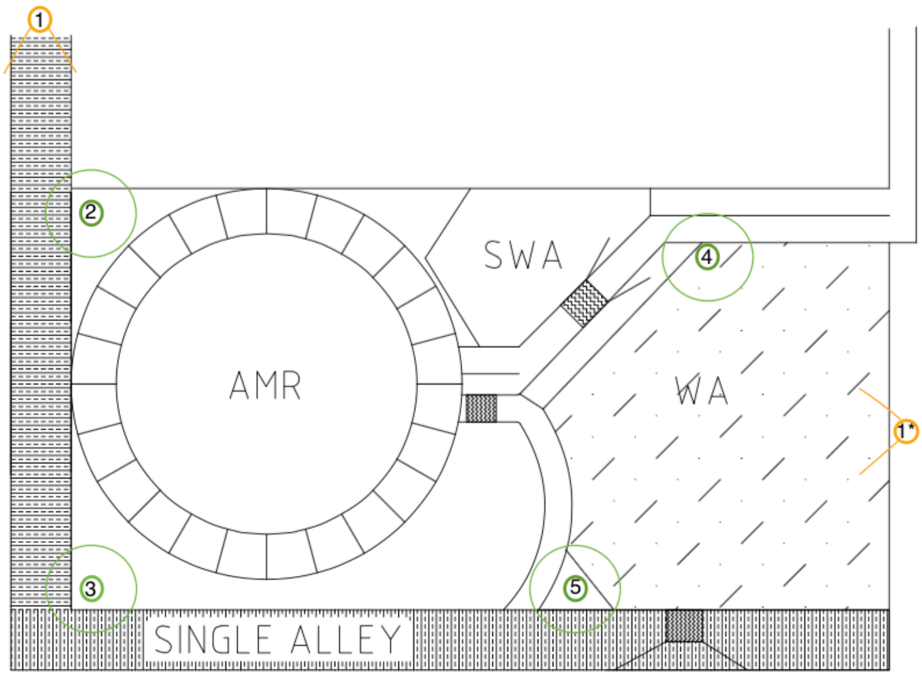


*Figure 2.* Green and orange circles indicate where cameras were located. Green marks indicate fisheye cameras and orange marks regular surveillance camera. The orange marks 1 and 1* are the same camera with different locations during the treatments. Camera 1 was used during SA and 1* during WA. Note that the visual field is not marked on the drawing. All view fields were overlapping.

Mainly three cameras were used for behavior analyzing, no 1*, 4 and 5 (fig. 2). The analysis of social interactions in the two treatments was limited to the entrance and a small area in front of the AMR (fig. 3). The areas were approximately 6.5 $m^2$ and 7.3 $m^2$ for SA respective WA.

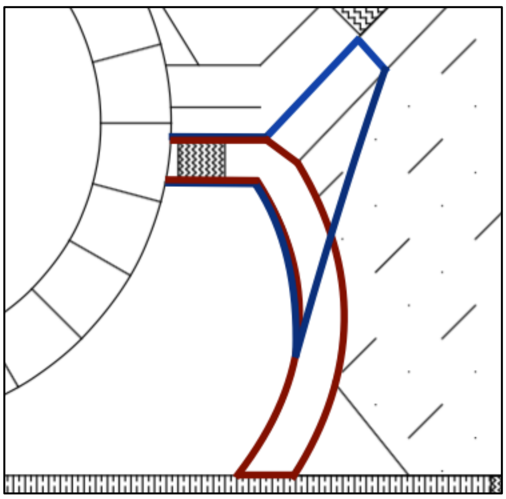

*Figure 3.* Outlines of areas used for analyzing social interactions. Red lines indicate area for the treatment SA and blue for WA.

Behavior was analyzed from continuous observations of recorded videos during the whole milking. From first cow entering the AMR to the last cow in each group entering the platform. The ethogram used for behavior observations is shown in table 2. During each experimental treatment 6 milkings were analyzed for social behaviors.

*Table 2.* Ethogram of behaviors and definition used for analyzing. Including description of each behavior, category belongings and source of behavior and the description.

| **Behavioral category** | **Behavior** | **Description** | **Author and study** |
|---|---|---|---|
| Aggressive | Butting | Punch with head on the body of another cow. Usually neck, shoulder or rump. Short time behavior, less than 1s. If there are several actions during 3s it will be calculated as one interaction. | Dickson et al. (1967), Reinhardt et al. (1978), and Bouissou et al. (2001). |
| | Pushing | Pressing body against on another cows body and giving a push. Registered if it occurs for a longer time (2s or more). | Rousing and Wemelsfelder (2006). |
| | Displacement | When a butt or push from a cow results in a withdrawn from the attacked animal. Registered when a cow flee from the actor cow, or trying to. | Huzzey et al. (2006), and DeVires et al. (2004). |
| Other | Chin on rump | Placing chin on the rump of another cow. Registered when it occurs 1s or more. | |

## Time required for milking

Gate passages were automatically collected by the herd management software DelPro™ (DeLaval International AB, Tumba, Sweden). From this data different time intervals were obtained for each cow and treatment. The milking order for the first and last 5 cows in each group and treatment was also checked using data collected by the DelPro software. Three different datasets for investigating *waiting time*, *milking time*, and *total time for milking procedure* were analyzed.

In the *waiting time* dataset, the time from when the cow left the pen to the time when she entered the AMR was calculated. Cows had to walk slightly longer to reach the AMR in the WA treatment, but this was assumed to be negligible.

*Milking time* corresponds to the total milking time for one cow. It was calculated from when a cow entered the AMR until the time she exited the AMR and was completely milked. If a cow was not completely milked during one milking she would be redirected into the AMR, and as some cows might get redirected several times, this time was added to the total milking time.

Total time spent away from pen, is referred to as *total time for milking procedure*. This includes time for walking to the rotary, waiting to entering AMR, milking, and time for returning to pens. During this time, cows were not able to eat, drink or lie down.

## Statistical analysis

### Behavior data

For analysis of behavior data, numbers of interactions were registered in Microsoft Excel (2010). Each behavior was summarized for each treatment day and group (*G1* and *G2*). Frequency of the behaviors was used to compare treatments with a Student's paired t-test in Excel. Differences between the two groups of cows are presented as MEAN ± STDEV.

### Analysis of time required for milking

The effect of treatment on *waiting time, milking time,* and *total time for milking procedure* was tested with linear mixed model (SAS 9.4, SAS Inst. Inc., Cary, NC, USA) taking repeated samples into account. The statistical model included the fixed effects of treatment and group. Interaction effect of treatment × group were also used. Cow nested within group was included as a repeated measurement. For the fixed effects least square means were calculated and differences between them were tested for significance by using t-test applying Tukey Kramer´s adjustments to avoid overestimations of differences. Data on milking time for cows is presented as LSMEAN ± SE.

Work time required for staff to herd cows was calculated using video recordings. Time elapsed from when cows left the pen until time when staff first interacted with the cows, approximately 40 minutes, were divided with the total number of cows that had entered the AMR giving the share of voluntarily entrance. Remaining time of the milking session was divided with number of cows left to be milked, giving work time required from staff. Data on staff working time is presented as MEAN ± STDEV.

# Results

Not all cows were present at all milkings analyzed (table 3). This was both due to regrouping and measurement failures.

*Table 3.* Proportion of cows that attended all 12 milkings for each variable.

| Data set | Attendance during 12 milkings |
|---|---|
| Waiting time | 48 % |
| Milking time | 72 % |
| Total time milking procedure | 58 % |

## Social interactions

In treatment SA overall more interactions occurred compared to WA ($p < 0.01$; table 4). Total numbers of interactions, at the entrance, were higher in the group *G1* compared to the group *G2* for the treatment WA ($p < 0.01$; table 5). No such difference was seen in for the treatment SA.

*Table 4.* Number of behaviors performed in the SA and the WA. P-values (Student's t-test) indicating differences between treatments for each behavior. NS = not significant.

| Behavior | SA (mean ± STDEV) | WA (mean ± STDEV) | P-value |
|---|---|---|---|
| All | 100.5 ± 23.9 | 35.3 ± 15.5 | < 0.01 |
| Butting | 43.5 ± 14.5 | 15.2 ± 6.4 | < 0.01 |
| Pushing | 24.0 ± 7.8 | 13.0 ± 8.5 | < 0.05 |
| Displacement | 35.2 ± 7.4 | 5.2 ± 3.4 | < 0.01 |
| Chin on rump | 7.8 ± 4.9 | 2.0 ± 0.8 | NS |

The social interactions butting and displacement were higher for the group *G1* in treatment SA compared to treatment WA for the same group ($p < 0.05$ and $p < 0.01$ respectively). Within *G2* had all interactions higher frequency in the SA than in the WA. Between groups, were both butting ($p < 0.05$) and pushing ($p < 0.01$) higher for *G1* then *G2* in the WA (table 5).

*Table 5.* Mean number for behaviors in the two groups, *G1* and *G2*, and significance levels between different comparisons. Groups compared within and between treatment SA and WA. P-values (Student's t-test) indicating differences between treatments for each behavior. NS = not significant.

| | Mean ± STDEV number of behaviors | | | | Significance level | | | |
|---|---|---|---|---|---|---|---|---|
| | G1 | | G2 | | G1 | G2 | G1 vs. G2 | |
| | SA | WA | SA | WA | SA vs. WA | | SA | WA |
| All | 51.8 ± 17.0 | 22.7 ± 7.4 | 48.7 ± 19.6 | 12.7 ± 9.1 | < 0.05 | < 0.01 | NS | < 0.05 |
| Butting | 21.0 ± 7.2 | 9.8 ± 4.4 | 22.5 ± 11.6 | 5.3 ± 2.5 | < 0.05 | < 0.05 | NS | < 0.05 |
| Pushing | 12.2 ± 6.5 | 8.5 ± 4.9 | 11.8 ± 5.0 | 4.5 ± 3.7 | NS | < 0.05 | NS | < 0.01 |
| Displacement | 14.0 ± 5.3 | 3.0 ± 1.0 | 11.2 ± 4.7 | 2.2 ± 3.2 | <0.01 | < 0.01 | NS | NS |
| Chin on rump | 4.7 ± 3.6 | 1.3 ± 0.9 | 3.2 ± 1.8 | 0.7 ± 0.7 | NS | < 0.05 | NS | NS |

## Waiting time

The time spent waiting in prior to milking did not differ between treatments. Although, waiting time was longer for *G2* than *G1* (37.83 ± 1.93 min and 28.48 ± 2.11 min respectively; $p < 0.01$; fig. 4).

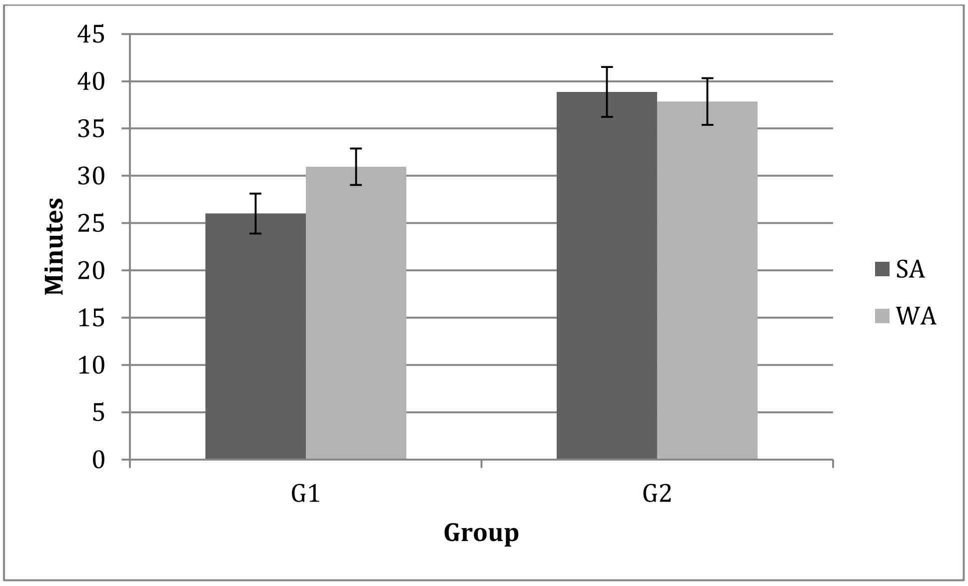


*Figure 4.* Average time spent waiting per cow and group for the treatments SA and WA (LSMEAN ± SE).

Cows redirected into the WA, due to incomplete milking, were found to block the entrance in the WA (fig. 7) and affect the cow traffic negatively. When cows were redirected for a second milking in the SA there were several situations where cows got exposed to aggressive interactions in an act of head-to-head fights.

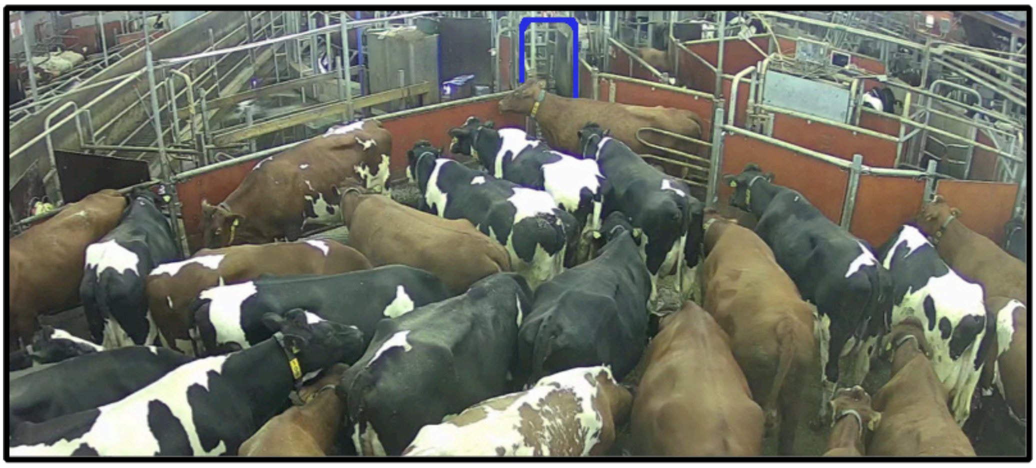

*Figure 7.* Cows in the WA with one cow blocking the entrance when being redirected. Entrance of AMR is located in the middle of picture at the top (highlighted in blue).

The proportion of cows entering the AMR without any herding from staff were considerably higher for *G1* compared with *G2* (82.0 ± 6.5 % and 45.0 ± 6.5 % respectively; $p < 0.001$; fig. 5). No difference was found between treatments, SA and WA. Situations occurred where cows were available to enter the AMR, but no cow voluntary entered (fig. 8).

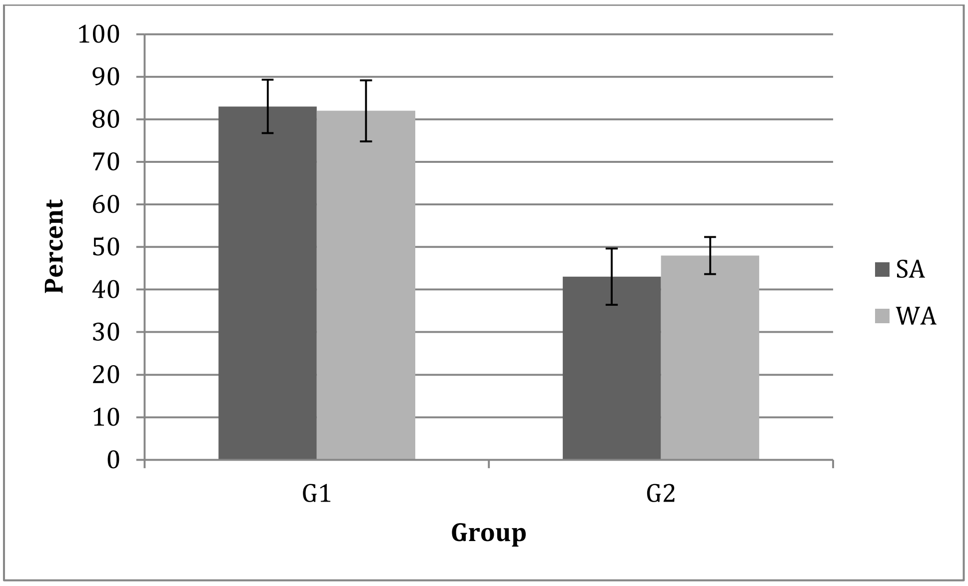


*Figure 5.* Percent of cows entered the AMR voluntarily without any herding from staff (MEAN ± STDEV). Time period from entrance of the first cow into the AMR and until 40 minutes elapsed since all cows was gathered into either of the treatments, SA or WA. After this point were staff allowed to herd cows.

*Figure 8.* The pictures show two separate situations in the WA where cows would not voluntarily enter the AMR, even though it was available and nothing was blocking the entrance (highlighted in blue).

No difference between treatments was found for the time required for each cow to enter the AMR with or without staff, however, the mean time per cow differed between groups. Without staff *G1* required less time in comparison with *G2* ($p < 0.001$; table 6). In contrary, *G2* needed less to enter the AMR when staff were present and herded cows ($p < 0.05$; table 6).

*Table 6.* Time required for each cow to enter the AMR in the two groups, *G1* and *G2*, including both treatments.

| | G1<br>Mean ± STDEV in seconds | G2<br>Mean ± STDEV in seconds | Significance level |
|---|---|---|---|
| Without staff | 75 ± 10 | 117 ± 18 | < 0.001 |
| With staff | 103 ± 34 | 60 ± 9 | < 0.05 |

In treatment SA, *G1* required less time than *G2* for each cow without staff (77 ± 10 sec and 125 ± 19 sec respectively; $p < 0.01$). Less time was also found in the WA without staff for *G1* compared to *G2* (73 ± 8 sec and 109 ± 13 sec respectively; $p < 0.001$). In the SA during time when staff were present did *G1* needed more time for herding each cow than *G2* (98 ± 19 sec and 57 ± 4 sec respectively; $p < 0.01$) (fig. 6). No difference was found in time when staff were present in the treatment WA.

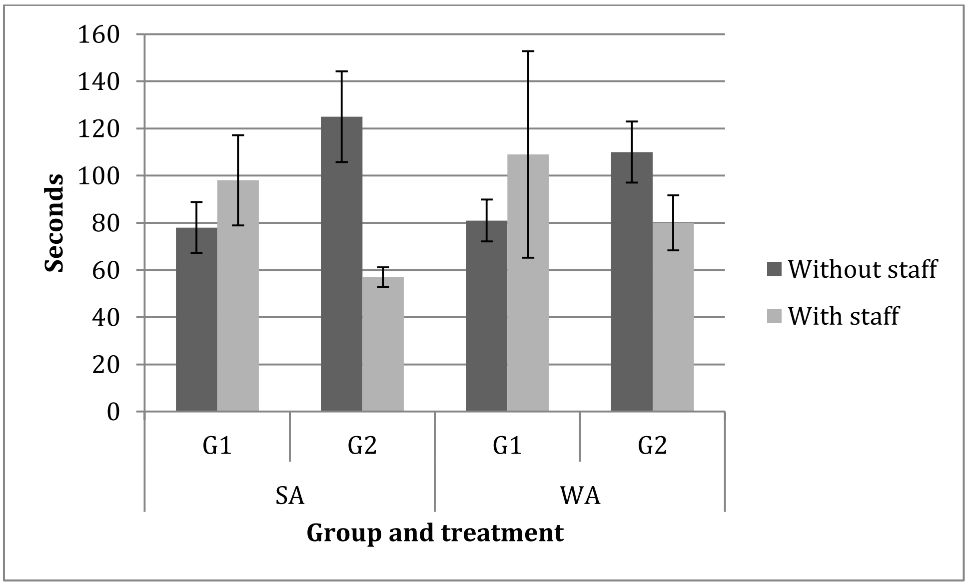


*Figure 6.* Mean time for each cow (MEAN ± STDEV) to enter AMR during time when staff did not interact with cows and time required for each cow when staff herded. Divided into groups, *G1* and *G2*, and treatments, SA and WA.

No consistent order of the five first and five last cows entering the AMR was found in either treatment.

### Milking time

No difference in milking time was found between treatments. Overall time for milking was shorter for *G1* compared with *G2* (13.51 ± 0.19 min and 14.13 ± 0.19 min respectively; $p < 0.05$).

Incomplete milkings occurred in total 76 times during both treatments. Three cows accounted for approximately 20 % of these occasions and three other cows accounted for 12 %. The remainder consisted of cows with one or two occasions of incomplete milkings.

### Total time for milking procedure

There was no difference between the two treatments. However, total time for milking was shorter for *G1* compared to *G2* (43.02 ± 2.15 min and 50.48 ± 1.95 min respectively; $p < 0.05$).

In 41 % of all milkings, cows were away from the pen longer than 75 minutes. In the treatment SA 19 % of the cows in *G1* and 60 % of the cows in *G2* were away from the pen longer than 75 minutes. In the treatment WA 24 % of the cows in *G1* and 55 % of the cows in *G2* were away from the pen for longer than 75 minutes. Shortest and longest time spent on milking was 17.6 and 172.0 minutes respectively for SA and 16.8 to 202.7 minutes respectively for WA.

# Discussion

## Social interactions

Aggressive behaviors might influence both cow traffic and milk production due to fear or discomfort (Rushen et al., 2008). Observed interactions around the entrance of the AMR were overall significantly higher ($p < 0.01$) for SA compared to WA. It was also observed that *G1* had a higher frequency of both butting and pushing than *G2* in the WA. This difference might have been an effect of more frequent regrouping in *G1* since heifers were included before calving, and therefore changes in the individuals included in the group, which increases aggressive interactions (Bouissou et al., 2001). However, all of these results could have been an outcome from the layout of the confined area, hierarchy within the group, management and competition of resources.

The frequency of aggressive interactions could have been a cause of competition for resources (Wierenga, 1990). Most likely a competition for being milked was not the case since cows in the present study, just like Prescott et al. (1998) discussed, seemed to have relatively low motivation for entering the AMR. Instead, the interactions might be an act of competition for space as cows have an individual preferred inter-cow distance (DeVries et al., 2004). Regardless of reason, interactions might still have affected the wellbeing of cows (Jacobs & Siegford, 2012). However, these results might be skewed, as results only indicate interactions in the restricted areas (fig. 3), which might not correspond to the total frequency of behaviors in the remaining of the whole HA before the AMR. These restrictions were made because the entrance was the one thing that was similar for both systems. Another reason for choosing that area to study social interactions, was that the entrance is a critical point of an AM system, cows that will not or cannot voluntarily walk through the AMR will have a negative impact on the cow traffic. If cows get exposed to aggressive behaviors it might affect the experience in a negative way (Jacobs & Siegford, 2012). The areas selected for behavior recording also includes an area where it can get crowded and cows cannot escape if they feel discomfort, especially in the SA. For a more adequate comparison between the treatments, interactions in the whole confined area should be registered, not only the entrance.

Even though aggressive interactions occurred more frequently in the SA, no difference between treatments was found for cows' willingness to voluntarily walk into the AMR. This could mean that cows in SA either did not find the interactions uncomfortable enough to effect the motivation to enter the AMR, or that the overall experience of milking was the same for cows in both treatments. If cows would find the situation uncomfortable the result should have differed between treatments (Jacobs & Siegford, 2012; Rushen et al., 2008). Thus, interactions in the whole area might not correspond to frequency in the analyzed area.

Displacements might indicate different things in the two treatments, as the cows have different ways cope with an interaction. In some cases, cows were not able to move when they were attacked from behind in the SA, as there were other cows blocking the way in front of them. In contrast, cows could more easily walk away in the WA as more space was provided.

Either way the interaction might have affected the exposed cow in a negative way (Bouissou et al., 2001; Albright & Arave, 1997). The results from this study cannot distinguish whether the displayed interactions were actions of dominance or aggression since interactions mostly was performed without being able to evaluate the outcome as mentioned by Beilharz and Zeeb (1982), but as stated by Wierenga (1990) contradictory displacements occurs both from dominate animals and subordinate. Another explanation for not moving when getting butted or pushed was that the confronted cow might not have found the situation threatening when an interaction was directed towards the rear part of the body compared to the head (Bouissou et al., 2001), but this seems to be highly individual and would still affect cows welfare.

The action of head-to-head fights in the SA, due to redirections of cows, would probably not have happened if cows had not been in a confined area where neither of them could escape the situation. As mentioned by Wierenga (1990) the housing can cause artificial interactions, which probably was the case in this situation. The same situation with head-to-head interactions did not occur in the experimental design WA due to redirection. Instead the entrance to the WA was blocked, (fig. 7) which was an obstruction to the cow traffic without causing aggressive interactions. The direction of incompletely milked cows when re-entering the AMR also decreased the efficiency of the milking since cows occupied a milking place even though this second milking probably did not result in future milk ejection or lower SCC (Nilsson, 2016; Lidholm, 2016).

### Waiting time and layout of the holding area

Differences in waiting time of 28.48 ± 2.11 and 37.83 ± 1.93 minutes between groups, *G1* respectively *G2*, might have been a result of group dynamics as *G1* mostly consisted of primiparous and *G2* of multiparous cows. Less time for waiting, regardless of treatment, was found for *G1* compared to *G2*. Reasons for these results might have been deduced to higher motivation for the younger cows or that cows in this group, *G1*, has not become used to being herded into the AMR, compared to the older cows in *G2*. As stated by Van Dooren et al. (2004) cows easily get used to being fetched, and this affects their own motivation negatively. Even though the AMR has been running in the herd for several years before implementation of this study staff were always present during the whole milking, constantly pushing cows on to the platform, which might have affected the motivation of cows to voluntarily enter. A higher percent of cows from *G1* entered the rotary voluntarily and had an overall shorter milking time per cow. Cows in *G2* required less time per cow when staff were present herding them. This might confirm the statement by Van Dooren et al. (2004) since a fairly low percent of cows in *G2* entered the AMR voluntarily. Older cows might therefore keep standing prior to milking, waiting for staff to be present before attempting to enter the AMR. The maximum technical capacity of the specific AMR used in this scenario is approximately 90 cows/h, and with used settings this was assumed to be a bit lower. Although, it should mean that approximately the whole group could have been milked during the time available before staff interacted. Cows that lack motivation to enter the AMR will slow down the milking process and increase work labor, which results in higher cost for the production, as the full capacity of the AMR is not used.

Lack of motivation for entering the AMR could be observed during video analysis. In the WA, several cows could enter the AMR, but did not. Many cows were standing in the correct position for entrance (fig. 8), but instead of entering they were standing still ruminating. The unwillingness to enter the AMR could probably be explained by a low motivation to enter the AMR rather than distress or fear for being milked. In the SA the same thing could be seen, although the whole cow flow relied on the animal closest to the entrance of the AMR. Even though a cow in the SA wanted to be milked she was constrained if there was a cow in front of her in the alley. This clearly showed that the design of the area before milking impacted the milking efficiency. Different designs used in this research can influence cows in different manners. There is no recommendation of appropriate size or design of a HA for cows in the Swedish legislation, but there are recommendations available from international organizations and companies. CIGR recommend a space allowance of 1.4 – 2.0 $m^2$ per cow (Flaba et al., 2014) and DeLaval has a recommendation of 1.5 $m^2$ per cow and also recommend a layout of a more traditional HA with a funnel in prior to the entrance (Forss, personal communication, May 3, 2017). For both treatments the area before milking were approximately 100 $m^2$, providing 1.6 $m^2$ per cow. Although, it can be assumed that the body mass varied between *G1* and *G2*, were *G2* on average had a higher body weight since these cows on average were older and that body mass usually correlate with age, even though the same amount of cows were consisted in each group. Therefore, might the available area for each cow before milking differed between the two groups, and should instead be valued as the Swedish legislation of space requirement for transportation of cattle that was based on body weight. The design of the SA, with a narrower raceway, might have taken advantage of cows' motivation for entering the AMR as cows with high motivation can push from behind and make other cows to walk forward, where as in a wider WA the same effect will not be seen. However, depending on the hierarchy in the group, the movement in the SA would probably have been more affected by hierarchy than in the WA. Since the rectangle shape provides less space around each cow to pass by without causing any aggressive interaction due to act of hierarchy (Albright & Arave, 1997). It has been demonstrated that cows have a low motivation of being milked (Prescott et al., 1998) and this would probably have been even more pronounced for cows that have to enter the AMR for a second time. No reward was given the first time of milking, and therefore motivation for the second trial was probably even lower. In the return alley approximately two cows fitted, and sometimes 3 – 4 cows in a row were directed back to the AMR. When several cows in a row were redirected for milking and returned to the AMR by the return alley, they prevented other cows from exiting the AMR. This event affected both cows that were waiting to being milked and cows in the AMR due to total stop of rotation. It was also noticed that some cows hesitated to enter the return alley, perhaps due to the sharp corners of the alley, and then in turn caused blockage for cows exiting the AMR. By providing feed to increase motivation (Prescott et al., 1998; Prikelmann, 1992) for entering the AMR the cow traffic and throughput from HAs and return alley would probably increase, but would probably also increase aggressive interactions since the access to feed would be a higher valued resource.

As mentioned by Albright et al. (1992) only 2.8 % would enter a parlor voluntarily. In the present study 82 % of *G1* and 45 % of *G2* entered the AMR voluntarily. This result was remarkably high compared to Albright et al. (1992), however the previous study was conducted in a conventional milking parlor, where staff were present all the time and milked cows. Thus, this could have affected cows in a negative way depending on staff behavior and earlier experience of humans for cows (Jacobs & Siegford, 2012).

The design of the curved alley by Grandin (1980) was constructed for ease of herding cattle to slaughter, mostly from feedlots. The curved alley should be made with high solid walls so the cattle cannot look through it for efficient cow traffic and be curved in order to easily herd cows from the inner radius by using the flight zone cattle (Grandin, 1997). The layout of the SA in this research was not constructed as mentioned, but kept in the same form as it was originally built, curved but with no solid walls. The alley was built with the aim to make the milking proceed by itself. However, during several occasions cows walked into the curved alley, and then stopped to look over the walls and focused on something else instead of following the cow in front of them or proceeding on to the platform. This moment of distraction influenced the cow traffic into the AMR, but results from the present study showed no differences between treatments, indicating that either was the effect of the curved alley not shown due to incorrect design or that this type of layout does not function on dairy cows as feedlot cattle explained by Grandin (1997). Moreover, there were no difference between treatments in time required for the staff herding the cows, although there was a tendency for SA requiring less time for herding. This could after all have been a result of the effects from the curved SA described by Grandin (1980; 1997) and from the fact that it is easier to herd cows in a more narrow area, compared to the relatively wide WA. If the SA would have been constructed with high solid walls the result might have been different. Though, lack of flight zone in most cows included in this study could also influence the possibility to herd the cows as described for the curved alley.

During analysis was it observed that cows' preferred to stand on the part of the floor covered with rubber mats. In the raceway to the curved alley in the SA, rubber mats were covering half of the slatted floor and could be noticed that cows waiting in the raceway before milking usually were standing in a line on the softer surface. The curved alley was of solid concrete, which also could have impacted the cow traffic as cows did not want to leave the softer surface to stand on hard concrete, as cows prefer to walk on soft flooring (Jungbluth, 2003). Moreover, the type of flooring used in a waiting area might affect claw health (Cook & Nordlund, 2009). With regards to this observation would it be of interest to investigate if a rubber mat in the WA affect where cows were located. As seen in fig. 8, cows were usually standing at the rear part of the WA and therefore the most suitable position of a rubber mat, for enhancing cow traffic, would probably be at the area in front to the entrance and in the passage into the AMR. Positioning cows more closely to the entrance might affect the cow traffic into the AMR positively.

### Milking time and total time for milking procedure

Mean milking time was 14 minutes for both groups and treatments. When all MP were working with the default settings for cleaning teats and attaching teat cups, one rotation would take approximately 20 min. However, the rotation time is affected by the overall motivation for cows to enter the AMR, if cows hesitate to enter the rotary, the total time for milking increases. Only 82 % of the cows in *G1* and 45 % of cows in *G2* entered the AMR voluntarily. Reasons for the shorter milking time in the present study compared to the general estimation could be attributed to situations where cows in the AMR were affected by occasions where no other cow entered the unit, and decreased the milking time since an empty MP would not require any work time from the robotic arms. Neither would the occurrence of cows blocking the exit occur in the same manner, which also could decrease milking time. Another situation that could have affected the result was the frequency of not working MP that were turned off, and in turn leads to less MP to be filled up during each lap and thus decreasing milking time. Although milking time was short, this does not correspond to the total time required for milking procedure, which affects the overall performance. Cows have 2.5 h daily in their time schedule that they can put on the milking procedure, without affecting their productivity or health (Grant, 2007). In a production system with two milkings daily, this leads to a maximum of 75 minutes per milking spent away from feed, water, and resting area. Long milking times may have negative effects on cows' performance and health. In the present study, the cows were away from the pen for longer than 75 minutes in 41 % of the analysed milkings. The longest time the cows spent on one milking was 203 minutes, which is almost three times longer than the time each cow had for disposal according to Grant (2007). Undoubtedly, this high prevalence of long time away from the pen would have negative effected the production, even though parameters of this were not investigated.

In the present study, cows that were not suitable for AM were included in both groups. As stated by de Koning and van de Vorst (2002) not all animals are suited for this type of production. Some cows in this study could never be milked by the AMR, which often was caused by their teat and udder conformation. These cows with constant failure of teat cup attachment were put on no milking, and got milked manually. These cows were not allowed a second milking, but still there were a total of 76 occasions where cows were redirected for being milked a second time. The redirection caused a reduced efficiency of the AMR since these cows got milked more than once for each milking, and thereby affected the number of milked cows per time unit, and cow flow for both entrance and exit of the AMR. Cows not suitable for this system also resulted in a higher workload, since manual work was required. However, milkings with unsuitable cows would probably have less impact on the total milking time than the reduced milking efficiency due to low motivation of entering the AMR among cows which resulted in empty milking places in the AMR.

One way to decrease the total time of milking and make cows return to the pens as quickly as possible after milking is to provide fresh feed on the feeding table upon milking. However, the housing system in the current study did not allow all cows to eat simultaneously, the proportion cows:feeding place was 3:1 and 2:1 for *G1* respective *G2*. According to Swedish legislation, it is acceptable to have up to three cows for each feeding place when feed is available *ad lib.* This means that cows should have the possibility to eat also before leaving for milking which might counteract the effect of providing fresh feed upon milking.

The first and last five cows to be milked varied in both treatments and no consistency in milking order was found. According to earlier studies, cows that left pens first also entered the parlor first (Soffié et al., 1976), and it was also stated that cows that enter the parlor first have a high social position in the group, but are not dominant. Soffié et al. (1976) also concluded that the entrance order and milk production did not correlate. But in contrary Rathore (1982) observed cows that entered first had a higher milk yield and lower SCC. In contrast, Olofsson (2000) found that high-ranked cows would get access before cows with lower rank. This makes it had to draw any conclusions whether the order can be related to hierarchy status, production level or a coincidence of where cows were located in pens during the let out and therefore affects the order of leaving at gathering for milking. Only 72 % of included cows were present during all 12 milkings, which also could have influence the result. Hierarchy was not studied in the present study, but no trend was found in the five first or five last cows to exit the pens and enter the AMR.

The results from the present study only gives the time spent herding the cows after staff were allowed to interact with cows. No recordings of labor time were made for preparation of the milking system or gathering cows to milking from the pens. Time for herding was higher in both groups than earlier investigations of work time, except for *G2* in SA. Time required was 1.9 MPMC in this group. Gustafsson (2009) found a requirement of 0.89 MPMC for AM system and 2.15 MPMC in a rotary parlor. During time when staff were not allowed to herd cows, time was put on activities not related to milking. Herding was only performed for some cows and not the entire group, which reduced the total time required of herding. As mentioned previously, AMR milking is comparable with both AM system and conventional rotary milking, but labor for the milking activity as such is reduced in an automated system. More detailed analyses need to be done to fully understand how work time was affected by the different cow traffic solutions but this was not possible to do within the current study. At the time when this thesis was conducted, no study of work time in AMR system had been done, making it difficult to compare required time with earlier findings.

### Study limitations

During video analysis situations might have occurred when interactions between cows were missed, due to human errors. Many interactions might occur at the same time and it could also be difficult to determine whether an interaction arose and that cows actually touched each other. This could have given misleading results for interactions in both treatments. To minimize prevalence of this error would it be of interest to have cameras placed straight ahead of areas where interactions were measured, and also to reduce the factor of having interior blocking the view.

At the research center several studies as well as educational activities were performed at the same time as the present study, and several different demands are therefore put on staff and cows. For this reason, frequent regrouping occurs and in the present study the proportion of cows that attended all 12 milking was 72 %. Regrouping has been showed to increase the antagonistic interactions with ten-folded in a group of cattle during the first hour (Bouissou el al., 2001). This could lead to higher amount of aggression than would appear in a group of cows with a more consistent constellation. This could also be an explanation for difference in performance of aggressive interactions.

The length of the habituation period might have affected the result and caused carry-over effects on cows' performance between treatments. A longer period between treatments would be desirable to get a fair result if time and resources was not limited.

## Further research

Milking efficiency in this study was unsatisfactory and was probably mainly affected by the low of motivation for entering the AMR. Since previous studies have shown that feed is highly valued in dairy cows it would be of great interest to conduct research on the effect of inclusion teaser feed in the AMR in a system with batch milking. In addition, it would be of interest to investigate the effect of a crowding gate in a WA to evaluate if this technical device can improve cow traffic and throughput at the AMR.

It would also be of interest to do a similar study, but look at the dominance value of the included cows. This to investigate if the hierarchy affects the frequency of performed aggressive behaviors and then evaluate if the occurrence of interactions can be deduced to the design of the area before milking, or if it is linked to some cows with a specific social position. Measuring interaction in the whole HA would also be needed to get a fair comparison of the two treatments. It would also be relevant to have consistent groups of cows balanced for lactation number and stage of lactation, for evaluating the two treatments in a more fair way, since several factors affect the outcome.

## Conclusions

Aggressive interactions were more frequent in the SA compared to WA. However, the area of analysis was restricted and might not have caught every interaction performed in the whole holding area. No difference was found between treatments in time spent on waiting, milking, total time away from the pen or time of herding. The group *G1*, predominantly primiparous cows, required less time for milking. The group *G2,* predominantly multiparous cows, required less time for herding. Generally, total time away from the pen for milking was long, which was believed to be an effect of the cows' low motivation for entering the AMR. Future research on the efficiency of the AMR is needed to reduce the time required for milking, since this is likely to affect the cows' performance and health. In addition to this, behavioral research on the experience of the waiting time in the whole area prior to milking should be conducted since voluntary entrance into the milking unit is a critical point in AM systems.

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